Building resilience
achieving effective post-disaster reconstruction

i-Rec 2008

Who Knows Best? An Overview of Reconstruction after the Earthquake in Bam, Iran

Mehran Gharaati, McGill University
email: mehran.gharaati@mail.mcgill.ca

Colin Davidson, University of Montreal
email: colinhdavidson@sympatico.ca

Abstract

In the earthquake which hit Bam in December, 2003, thirty-five thousand people lost their lives and widespread damage was caused, leaving 75,000 people homeless. It seemed that the traditional construction methods (adobe) were at fault but on closer examination, this does not appear to be the case. Instead, poorly understood non-traditional building techniques appear to be the prime causes. The immediate post-disaster reconstruction program was supervised by the Housing Foundation of the Islamic Revolution (HFIR), who (i) proposed designs of standard steel frames for single family houses, (ii) arranged for national or foreign suppliers to propose approved house designs, and (iii) provided inspectors who oversaw step by step the building processes and authorized payment of the government reconstruction grants.

Once the main phase of reconstruction was completed, the HFIR inspectors began to withdraw but building continues, generally employing small local builders with some self-help building, within the habitual regulatory structure of local building inspectors. The question is: have the lessons of earthquake-safe construction been learnt? If yes, who has learnt them and are they applied?

To answer these questions, a three-phase field study was organized in Bam (i) immediately after the earthquake, (ii) during the reconstruction program and (iii) after the dismantling of the HFIR's presence. Surprisingly, it was found that not only is earthquake resistance a prime concern of the average householder – a concern shared by the majority of builders – but also that it led to considerable

over-design and concomitant waste of resources, to the detriment of other qualitative aspects of housing.

Keywords: earthquake resistant construction, knowledge acquisition, supervision, technical innovation, traditional building

Introduction

One of the key issues in post-disaster reconstruction is the role of the survivors. Can their participation be mobilized and, if so, what knowledge and skills can they bring to the task. The answer to this question depends, to a large measure, on the organizational strategy deployed for the reconstruction process, which in turn depends on the prevailing administrative structures and on the attitudes of the population regarding them.

The aftermath of the earthquake in Bam, Iran, provided the context for a case study of the concerns of the survivors and their ability to ensure that they were translated into appropriate construction methods. Was the principal preoccupation about reconstructed housing related to the suitability of the design of the houses and the composition of the neighborhoods, or was it focused on “invisible” features such as structural capability?

To obtain answers to these questions, a three-part semi-longitudinal research was conducted in Bam, in the interval between the earthquake and reconstruction, during the formal reconstruction phase and once formal reconstruction was virtually finished.

Background

Located in southeast of Iran, the city of Bam was hit by a 6.7 magnitude earthquake on December 26, 2003, which severely damaged the city. According to the International Federation of Red Cross and Red Crescent Societies, approximately 35,000 people died, and more than 75,000 residents (out of a population of 120,000) were left homeless; as many as 85% of the city’s buildings were destroyed or damaged (Walter 2004).

It is well known that building with earth has a long history in Bam, dating back some 2500 years to when the city was founded. The earth architecture, therefore, was the traditional form of construction in Bam and the majority of older houses in Bam were built out of adobe and raw soil. Therefore the high level of destruction throughout the city was first thought to be the result of these supposedly poor construction materials. All the early reports from the earthquake stressed that the construction material - composed mostly of raw clay and adobe - was at the roots of the high level of destruction.

A closer look at what remained of the city, however, revealed that this is not the whole story. First of all, while the majority of earth buildings in the *new* city were demolished, a number of earth structures in the *old* city were still standing[1]. Furthermore, although to the visitors and reporters who visited the ruins of Bam immediately after the earthquake, it looked as if almost all of the city was constructed of adobe brick, the statistics shows that 54% of the houses were made of adobe, and the rest (46%) were built using modern materials like steel and concrete (Ghafory-Ashtiany and Hosseini 2007). In point of fact, there were many newly built buildings that were also destroyed or seriously damaged (Murphy, 2004) (see Figure 1 below).

Fig. 1. Aerial photo of Bam one day after the quake (IKONOS, 2003)

From a proper examination of the evidence that could be observed in the ruins of the city, it seems that poor workmanship and lack of construction know-how were the main causes of the devastation, regardless of whether the buildings were made of earth, concrete or steel (Naeim *et al*., 2004). This is the basis for the research reported on here.

[1] The Citadel, one of the world's largest earthen structures, was badly damaged; it appears that recent inappropriate repairs were likely to be the reason.

Reconstruction

After the "emergency shelter and recovery" stage of the post-earthquake response, the reconstruction efforts got started at all levels from the local to the national government. Within one month after the disaster, the Housing Foundation of the Islamic Revolution of Iran (HFIR) "was put in charge of the reconstruction of Bam, including housing, commercial units and infrastructure" (Astaneh-Asl *et al*., 2006).

Building upon their experience and the lessons drawn from previous post-disaster reconstruction programs, HFIR took a relatively open approach this time - an approach that had never been used before in post-disaster programs in Iran. Whereas earlier programs had top-down characteristics, and were rather closed to participation of the stricken community, a combination of top-down technology-based and bottom-up community-based approaches was employed in the Bam reconstruction project. This approach provided citizens with the opportunity to choose from a variety of reconstruction methods and materials, in such a way that new technologies and materials were introduced to the locals and people were involved in the decision-making process to a certain extent (Gharaati, 2007).

Research Question

Research questions:

- When there is a strictly regulated program of reconstruction with administered controls, how readily do the survivors and their contractors actually learn and retain the "good practices" proposed by the program?
- Once the formal reconstruction program is finished and the supervising authorities withdraw, are the lessons forgotten and previous lax methods of construction adopted again?

Although the physical outcome of the reconstruction program of Bam has been acclaimed as a great success (Astaneh-Asl *et al*., 2006), its long-term success is open to debate. It is true that the houses built in Bam in the official reconstruction period meet all the earthquake-resistant building requirements of Iran, thanks to the use of preferred model constructions and rigorous inspection procedures by HFIR along with other pertinent parties. Nonetheless, one can hypothesize that the good practice of earthquake-resistant construction might be limited to that specific time frame of HFIR's presence in Bam, and would not be continued *indigenously* after the termination of the formal reconstruction program.

Research Methods

The research was organized longitudinally. A *first* visit to Bam in February 2005, shortly after the earthquake, provided – on the basis of observations - information about building failures. A second visit a year later (February 2006) enabled the formal reconstruction process to be described, based on interviews with the HFIR inspectors and with the providers of the selected model houses, and on prolonged observations. The third and final field trip (in the winter of 2007-2008) - once the HFIR had completed its three-year presence in Bam - involved obtaining information from small building contractors and their clients on how they chose their building techniques once the discipline of the HFIR had been removed. Gathering this delicate information was performed through actual hands-on participation in building work.

The information obtained from these three field studies in Bam enabled a view of the reconstruction process to be constructed, and provided the platform for responding to the research hypothesis, namely:

- *information about techniques acquired during the formal supervised reconstruction period were not interiorized and were not transformed into operational knowledge and skill, so that construction reverted to earlier relatively unsafe methods.*

Results

As is the case with many post-disaster projects in developing countries, the reconstruction program of Bam focused on improving the quality of building materials and introducing new construction methods. The HFIR developed a standard structural frame and also imported a number of new earthquake-resistant building techniques, which were then showcased to the locals. The aim was to replace the traditional building methods and materials with selected new ones. The structure proposed by HFIR is composed of prefabricated steel posts, beams and bracings that are designed in a way that can easily and quickly be assembled, using only bolts and nuts for fastening the elements together (Figure 2). All the construction methods offered by building practitioners or companies other than HFIR either used HFIR's prefab frame and light-weight materials, or proposed reinforcing strategies for masonry buildings, or offered the use of light-weight materials with a conventional steel-frame structure (i.e. steel post and beams that are welded together in-situ) (Figure 3).

Fig. 2. The structure proposed by HFIR

For further information about the strategies proposed by HFIR, see: Gharaati, 2007. In all cases, the technique chosen by each beneficiary family was then controlled by HFIR through a series of inspections during the construction process.

Fig. 3. The model houses proposed by HFIR (left) and by other invited enterprises.

The reconstruction program was scheduled for a period of 3 years; HFIR discharged its duties and then left Bam. With HFIR gone, the inspections as well as the funding incentives and grants were gone, too. Subsequently, it was possible that there would be a reversion to faulty implementation and “cutting corners”, especially in the informal housing sector. The three-part field study was precisely designed to detect whether this was the case.

First field study

Bam presented an image of desolation in the immediate aftermath of the earthquake. Many buildings had been erected with “new” methods of construction (hybrids of concrete or steel frames, brick masonry infill, and concrete and hollow tile floors) simply broke apart (Figure 4, next page). Essential junctions between structural elements failed, and heavy secondary elements fell. An examination of the typical failures revealed that reinforcing was inadequate or virtually non-existent; bonding between different materials was not installed properly or left completely out.

A lack of construction knowledge among a majority of the laborers and masons, along with inadequate building inspection made many buildings in Bam vulnerable to the earthquake. By and large, the problems with the implementation were: first, problems occurring because of improper or poor construction materials, and second, problems arising from poor workmanship and construction details. Traditional earth and vaulted construction fared slightly better, but often failures stemmed from non-observance of basic principles about compact plan forms (Gharaati, 2007).

Second field study

Two years after the earthquake, the HFIR had succeeded in launching the reconstruction program and had developed its two-prong strategy: (a) design and promotion of a standard steel frame and (b) the display of earthquake-safe model houses prepared by invited companies from Iran and overseas. As mentioned above, both approaches were accompanied by a tight program of technical monitoring and financial control.

Fig. 4. Faulty building practice in Bam resulted in the high rate of casualties caused by the earthquake. (Photo source: HFIR).

Second field study

Two years after the earthquake, the HFIR had succeeded in launching the reconstruction program and had developed its two-prong strategy: (a) design and promotion of a standard steel frame and (b) the display of earthquake-safe model houses prepared by invited companies from Iran and overseas. As mentioned above, both approaches were accompanied by a tight program of technical monitoring and financial control.

Adopting the standard frame allowed for a certain degree of design choice by the beneficiaries; adopting the model house approach did not. The statistics about the use of standard houses seems to indicate that this “take it or leave it” strategy fell foul of the specific life style and ensuing functional requirements which are important for the citizens of Bam. On the basis of unverified information, it appears that very few of the standard houses were actually chosen, probably because of the lack of flexibility that this route allowed for and the misfit between the house designs and the preferences of the users.

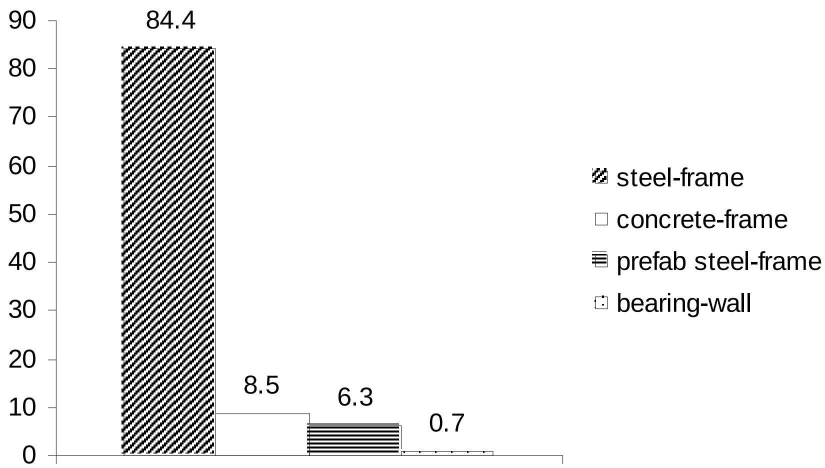

Fig. 5. The percentage of each technique adopted by the residents

An examination of this main phase of the reconstruction program of Bam confirmed that although all the new houses built in the reconstruction period were built up to the national seismic building codes and would definitely withstand earthquakes, the long term continuity of producing earthquake-resistant construction was not thought of. While all the seismic building code requirements were being strictly enforced by the HFIR's continuous inspection policy during the reconstruction period, the driving force for maintaining good implementation into a longer-term future remains unaddressed. In the context of this research, this situation raises questions like:

- Have the lessons of earthquake-safe construction been learnt?
- How one can make sure that people will keep up with the good practice of implementation?
- What are the driving forces to maintain the good practice?
- How could the continuity of earthquake-resistant building techniques be achieved in Bam?

The third field study was designed to address this question head on.

Third field study

The objective of the third field study was to ascertain whether, in fact, lessons had been learnt during the period covered by the HFIR and whether they translate into safe construction methods. Gathering the relevant information could not be based on an explicit survey or questionnaire, since respondents would obviously slant their responses and provide "good" answers. Instead, a more subtle but time-consuming strategy was required. In this approach, the lead author took on tasks within several small construction "companies" (that is to say, artisans organized in informal networks), enabling him to see how work was really performed and to get a feeling of how decisions were made and on the basis of what principles. The work involved in this fieldwork was basically labour, including any sort of low-importance construction work such as carrying bricks, helping move materials and so on. The intention was to not disturb the normal performance of the builders, or not to exert any influence on their regular practice. Instead, as described, the objective was to identify how the experience acquired working under the supervision of the HFIR did or did not translate into a new form of knowledge-based practice

According to the model of knowledge creation and transfer proposed by Nonaka and Toyama (2004), tacit knowledge is accumulated and shared through socialization. Maznevski and Athanassiou (2007) also emphasize that "important knowledge travels best through personal relationships", and point out that the most effective way of sharing tacit knowledge is "through deep dialogue that comes with personal relationships". Therefore, to examine the tacit knowledge of the local builders, one must build close relationship with them, get into their community and eventually work with them in order to get a fairly comprehensive understanding of what they do and how they build.

Overall, two strategies were felt to be the most effective in gaining the trust of the local builders. First, getting to know the local (master) builders through their clients (citizens), and second, to spend time working with them for a certain period. Used together, this approach can create a sense of confidence and trust towards the researcher among the local builders' community – who in fact ceases to be perceived as an observer. Nonaka and Toyama (2007) believe that "practice lays a foundation for sharing tacit knowledge through shared experience". Thus, practicing construction with the local builders seemed to be the best way if one wants to find out about their tacit knowledge.

The observation in Bam brought up surprising outcome. Not only the masons appear to know fairly well about the earthquake-safe construction, but also the locals seem to have gathered a lot of knowledge, which they admit they didn't know at all before the earthquake. Through conversation and informal interview, it was found that the locals have attained this know-how from the inspectors, with whom they had close relationship daily basis during the official reconstruction period.

Another surprising finding was that the informal buildings appeared to be more warily built compared to the formal ones; all parts of the structure were considerably oversized. In contrary to what was expected, namely that people might cut corners in the informal sector to save money, they overdo everything to make sure their building is safe. In fact, during the official reconstruction time, the inspectors did not care about the overuse of steel or concrete in the construction. On the other hand, people assume that using more steel and concrete would make their building stronger. Consequently interventions of the owner/builder towards overdoing the structure can be seen in almost all of the informal buildings built after the HFIR era. Heavy frames for single or double storey houses are erected, using too much steel, too many gusset plates, and overly thick cross bracings and reinforcement plates. To be (supposedly) on the safe side, even those builders who have engineer-designed drawings and specifications for a building would move to one size or two over what was specified on the drawings.

Discussion

Learning from experience

Earlier experience showed that importing new construction materials and modern techniques was not the answer by itself, as shown by the experience of another earthquake-stricken Iranian town, Ghaen. An earthquake struck Ghaen in 1981 and led to the death of about 1,500 people. The city was reconstructed, using new construction materials and methods; all houses were designed by engineers to withstand earthquake. Nonetheless, when another earthquake hit the city 16 years later (1997), more than 1,500 people lost their lives again (Murphy, 2004; Shaoul, 2004) – apparently mainly those living in the rebuilt houses. Indeed, many observers believe that the further death toll was the result of inconsistency in implementing the seismic building codes (Murphy, 2004), though Iran had established seismic building codes as early as in 1989 (Ghafory-Ashtiany and Hosseini, 2007).

In fact, one key element is missing in many reconstruction programs, if not in all of them, namely the transfer of experience and knowledge imposed from outside (by, in this case, the HFIR) and used in a "subservient" situation by the builders (who have to "do what they are told to do"). Does the builders' work experience under the control of the HFIR translate into usable tacit or explicit knowledge? In other words, does the imported explicit knowledge (of earthquake-resistant building, familiar to the HFIR designers) turn into the tacit knowledge of the local builders and their clients? As Takeuchi and Nonaka point out, "Tacit knowledge is personal, context-specific, and therefore hard to formalize and communicate" (Takeuchi and Nonaka, 2004).

Knowledge creation

The creation of operationally effective tacit knowledge calls for a lot of person-to-person communication and establishment of close interpersonal relationships – which may or may not have been the case between HFIR officials and the local builders, particularly as converting explicit knowledge into tacit knowledge is a very time-consuming and difficult process. Davenport and Prusak (1998) emphasize that "tacit knowledge transfer generally requires extensive personal contact", adding that it cannot be transferred in any other way. Transferring tacit knowledge involves close personal contact, relationship, and "physical proximity" (Nonaka and Toyama 2007).

Although explicit knowledge travels easily from one person to the next, tacit knowledge is much more difficult to share. The most effective way of sharing it is through deep dialogue that comes with personal relationship (Maznevski and Athanassiou, 2007, p.74).

Unlike tacit knowledge, however, explicit knowledge can be easily packaged for transfer. But tacit knowledge is "sticky", as Ichijo and Nonaka (2007) put, and thus very hard to express and transfer. Therefore, attaining tacit knowledge takes practice and is "closely related to 'learning by doing'". Experience gaining through practice is the vital part of embodying explicit knowledge in the hearts of the learners (Nonaka and Toyama 2007).

The key to acquiring tacit knowledge is experience… The mere transfer of information will often make little sense, if it is abstracted from associated emotions and specific contexts in which shared experiences are embedded (Nonaka and Takeuchi 2004, p.55).

This observation suggests that reconstruction programs may very often fall into the trap of believing that the knowledge about safe-building is simply transferred by publishing technical pamphlets, showcasing the techniques, and/or bringing new materials in. These measures can only transfer the knowledge that is "transmittable in formal, systematic language", which is basically resembles information rather than of 'know-how' (Takeuchi and Nonaka, 2004).

The objective of the research, and particularly in this third phase of the field study, was to find out how well the earthquake-resistant building techniques proposed by HFIR were adopted by the local builders. In other words, the goal was to examine whether the local builders had successfully turned the explicit knowledge disseminated by HFIR into tacit knowledge, which they could continue to use in their day-to-day work.

In summary, it seems that although the local masons and masons do well know what measures to take in order to reinforce the building against earthquakes, they do not appear to completely comprehend the concept. In other words, they know which components are important in reinforcing the structure against seismic shocks, but may not necessarily understand what are the underlying principles.

It is evident that earthquake-safe building *techniques* have been successfully transferred to the local builders and their clients, but it seems that the *knowledge* underlying those techniques has not been conveyed adequately. Happily, the close and frequent relationship between the inspectors and the local builders during the formal reconstruction period resulted in at least the locals' understanding of the earthquake-resistant construction (*what to do*). However, the process failed to transfer the knowledge of earthquake-resistant construction (*why to do it*).

The research hypothesis, that "*information about techniques acquired during the formal supervised reconstruction period were not interiorized and were not transformed into operational knowledge and skill, so that construction reverted to earlier relatively unsafe methods*" is not confirmed. On the contrary, the citizens and builders of Bam acquired considerable knowledge which they applied in their subsequent work.

More generally, this research highlights the importance of ensuring that the post-disaster reconstruction period allows for the generation of tacit knowledge within the community and its builders. However, to be feasible, a complete transfer of knowledge may take longer than the time which is available within the short to mid-term horizons of reconstruction programs.

Key lessons learned:

- In a reconstruction program, it is essential to allow for transferring pertinent knowledge to the receiving community.
- Transferring technical knowledge is easier than creating an understanding of the reasons for it.
- Creating tacit knowledge in the receiving community and its builders takes more time than is usually available, suggesting the need for careful up-front planning.

References

Astaneh-Asl, A., M. Saeedikia, et al. (2006). “Reconstruction of Housing Destroyed in the 2003 Bam-Iran Earthquake”, in: *100th Anniversary Earthquake Conference: Commemorating the 1906 San Francisco Earthquake*. San Francisco, University of Berkeley, Retrieved 10/11, 2007, from http://ce.berkeley.edu/~astaneh/Astaneh-et-al-8NCEE-Conf.2006-paper-Bam%20Reconstruction.pdf.

Davenport, T. H. and L. Prusak (1998). Working knowledge : how organizations manage what they know. Boston, Mass, Harvard Business School Press.

Ghafory-Ashtiany, M. and M. Hosseini, *Post-Bam earthquake: recovery and reconstruction.* Natural Hazards, 2008. 44(2): pp. 229-241.

Gharaati, Mehran, (2007). “An Overview of the Reconstruction Programme after the Earthquake in Bam, Iran”, in: Alexander, David, Colin Henry Davidson, Andrew Fox, Cassidy Johnson and Gonzalo Lizarralde, (eds.), *Post-Disaster Reconstruction – Meeting Stakeholder Interests*, Florence (Italy), the University Press, pp. 253-262.

Ichijo, K. and I. Nonaka (2007). *Knowledge creation and management : new challenges for managers*. Oxford ; New York, Oxford University Press.

IKONOS, (2003). IKONOS satellite imaging. Retrieved 05/12, 2004, from http://www.spaceimaging.com/gallery/spacepics/bam_ quake_SI_12_27_03.jpg.

Maznevski, M. and N. Athanassiou (2007). “Bringing the Outside In; Learining and Knowledge Management through External Networks”, Ichijo, K, and I. Nonaka (eds.), *Knowledge creation and management : new challenges for managers.* Oxford and New York, Oxford University Press: pp. 69-82.

Murphy, C. (2004, 02/01/2004). "Starting from scratch in Bam." Retrieved 07/10, 2007, from http://news.bbc.co.uk/2/hi/middle_east/3363125.stm.

Naeim, F., M. Mehrain, and M. Rahnama. (2004). “Preliminary Observations on the Bam, Iran, Earthquake of December 26, 2003”, *EERI Special Earthquake Report,* Earthquake Engineering Research Institute (EERI).

Nonaka, I. and H. Takeuchi (2004). “Theory of Organizational Knowledge Creation”, Takeuchi, H., and I. Nonaka (eds.), *Hitotsubashi on Knowledge Management*., Singapore, John Wiley & Sons (Asia): 47-90.

Nonaka, I. and R. Toyama (2004). “Knowledge Creation as a Synthesizing Process”. Takeuchi, H., and I. Nonaka (eds.), *Hitotsubashi on Knowledge Management*, Singapore, John Wiley & Sons (Asia), pp. 91-124.

Nonaka, I. and R. Toyama (2007). “Why Do Firms Differ? The Theory of the Knowledge-Creating Firm”, Ichijo, K., and I. Nonaka (eds.), *Knowledge Creation and Management: New Challenges for Managers*, Oxford and New York, Oxford University Press, pp. 13-31.

Shaoul, J. (2004). "Eyewitness in Iran: Bam Disaster And Beyond." Retrieved 07/10, 2007, from http://www.countercurrents.org/iran-shaoul140104.htm.

Takeuchi, H. and I. Nonaka (2004). *Hitotsubashi on Knowledge Management*. Singapore, John Wiley & Sons (Asia).

Walter, J., Ed. (2004). *World disasters report 2004: Focus on Community Resilience*. Bloomfield, CT., Kumarian.

Acknowledgements

The counseling of Professor Vikram Bhatt, McGill University, is gratefully acknowledged. M.G. is recipient of a scholarship received from the Art University of Isfahan, Iran.

Authors' biographies

Mehran Gharaati is PhD candidate at the School of Architecture, McGill University. He started his PhD in 2004, when he graduated with M.Arch.II degree from the Minimum Cost Housing group at the same school. Before going to Canada, he received his first M.Arch degree from the Art University of Isfahan, Iran, where he also practiced architecture as well as teaching for four years. Aside from hands-on practice of architecture, post-disaster studies and architectural education are his areas of interest.

Emeritus Professor and architect, Colin Davidson taught and conducted research at the Faculty of Environmental Design (Faculté de l'aménagement") at the University of Montreal, where he was Dean from 1975 to 1985, and where he is responsible for the graduate programs in Project initiation and management. Prof. Davidson's research brings a systems approach to project organization and procurement, information and communications within the building team, and to reconstruction after natural disasters in developing countries. Prof. Davidson has participated in the work of various CIB commissions, (including coordinating W102) since 1972. He has practiced as an architect in the U.K., the USA and Italy.